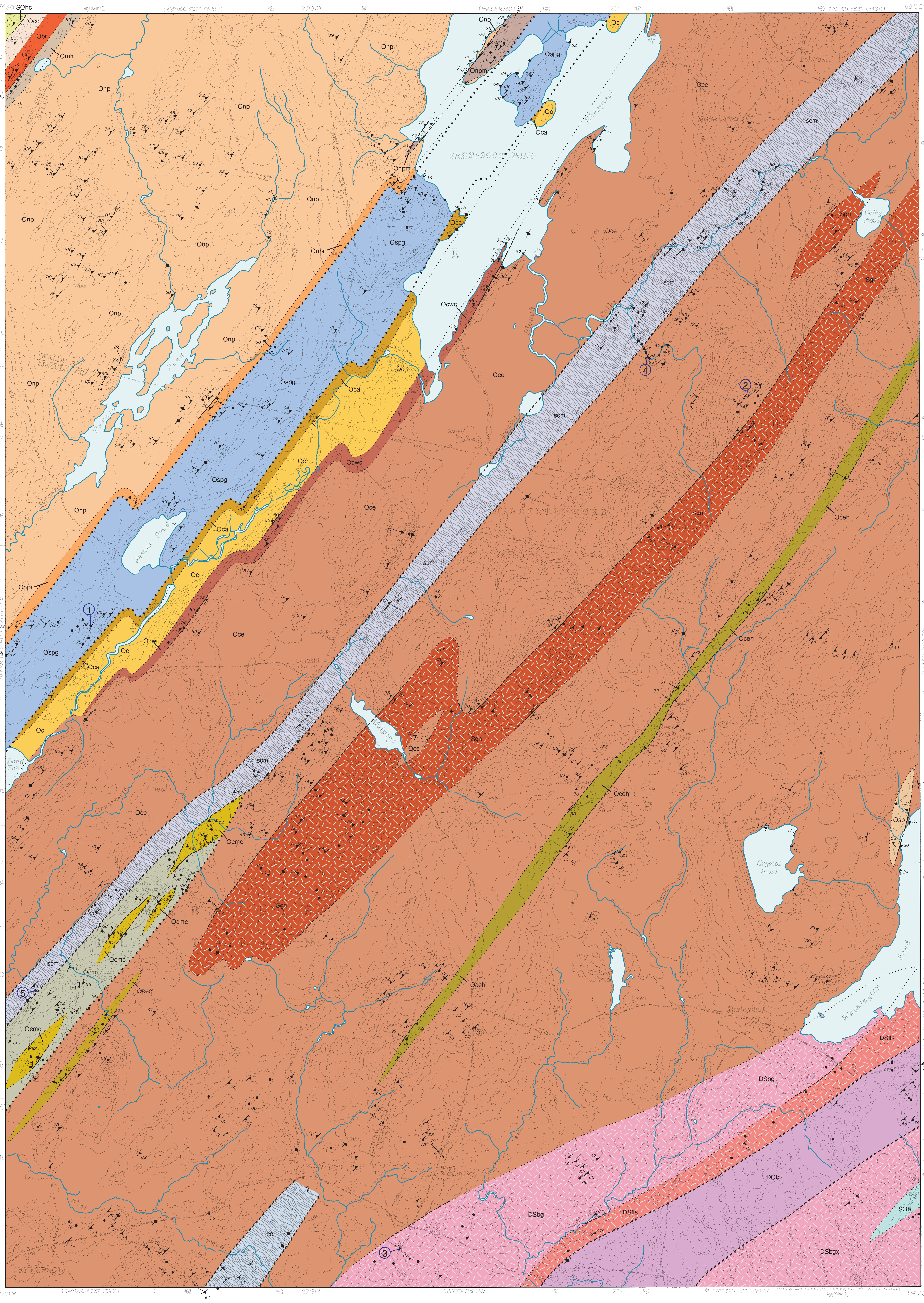
Bedrock Geology



Field work was conducted by D. P. West and E. M. Peterman during the summer of 2003. Additional field work was conducted by D. P. West during the 1990-1992 field seasons.

Quadrangle Location

SCALE 1 : 24,000

1 MILE — 1000 0 1000 2000 3000 4000 5000 6000 7000 FEET — 1 KILOMETER

CONTOUR INTERVAL 20 FEET

TRUE NORTH

Topographic base from U.S. Geological Survey Razorville quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

The use of industry, firm, or local government names on this map is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.

Razorville Quadrangle, Maine

Bedrock geologic mapping by
David P. West, Jr.
Emily M. Peterman

Digital cartography by:
Susan S. Tolman

Robert G. Marvinney
State Geologist

Cartographic design and editing by:
Robert D. Tucker

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Maine Geological Survey
Address: 22 State House Station, Augusta, Maine 04333
Telephone: 207-287-2801 **E-mail:** mgs@state.me.us
Home page: http://www.state.me.us/doc/nrimc/nrimc.htm

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EXPLANATION OF UNITS

STRATIFIED ROCKS

Central Maine Lithotectonic Belt

Silurian-Ordovician (?)

SOhc — **Hutchins Corner Formation.** Medium-gray, slabby weathering (slabs 2-10 cm), fine-grained, quartz-plagioclase-biotite granofels. This unit is poorly exposed in the northwestern corner of the Razorville quadrangle, but it is well exposed to the west (Weeks Mills 7.5' quadrangle, see Grover and Fernandes, 2003) and north (Palermo 7.5' quadrangle, see Newberg, 1985; Pankiwskyj, 1996).

Liberty-Orrington Lithotectonic Belt

Falmouth-Brunswick Sequence

Ordovician and Ordovician (?)

Occ — **Carrs Corner Formation.** Light gray, fine- to medium-grained, plagioclase-quartz-biotite granofels and gneiss. This unit underlies a small area in the extreme northwestern corner of the Razorville quadrangle, but is mapped more extensively to the north in the Palermo quadrangle (Pankiwskyj, 1996). A U-Pb zircon age of 460 ± 2 Ma from a metavolcanic layer within this unit in the Palermo quadrangle has been interpreted to represent the original depositional age of these rocks (Tucker and others, 2001).

Obr — **Beaver Ridge Formation.** Dark gray, medium-grained, very rusty weathering, sulfidic and locally graphitic, quartz-muscovite±sillimanite schist and granofels. The Beaver Ridge Formation is only exposed in the extreme northwestern corner of the Razorville quadrangle. More extensive exposures have been mapped to the north in the Palermo quadrangle (Pankiwskyj, 1996) and to the west in the Weeks Mills quadrangle (Grover and Fernandes, 2003).

Omh — **Marden Hill Formation.** Light gray, medium- to coarse-grained, quartz-plagioclase-biotite±staurolite±kyanite± garnet granofels. Thin sections reveal an abundance of fresh cordierite (typically rimming staurolite porphyroblasts), and lesser amounts of sillimanite. Additional rock types include light gray to greenish-gray, medium- to coarse-grained, biotite marble and calc-silicate granofels. The Marden Hill Formation is only exposed in the extreme northwestern corner of the Razorville quadrangle, but is mapped more extensively to the north in the Palermo quadrangle (Pankiwskyj, 1996).

Onp — **Nehumkeag Pond Formation.** A variety of rock types is found within this unit, but the dominant one is a light gray, fine- to medium-grained, plagioclase-quartz-biotite±garnet gneiss and granofels. Subordinate rock types include: (1) dark gray, fine- to medium-grained amphibolite that locally contains garnet, (2) light gray, fine-grained, plagioclase-quartz-actinolite±diopside-biotite granofels and gneiss, (3) medium gray, medium-grained, slightly to moderately rusty weathering, quartz-muscovite±sillimanite schist that locally contains coarse-grained garnet, and (4) light gray, fine-grained, plagioclase-quartz-biotite mylonitic gneiss. Layering, prominent at most exposures, is highly variable and ranges from 2 to 12 cm in thickness. Variably deformed muscovite-bearing pegmatite layers, lenses and boudins are ubiquitous. Overall, a sedimentary, or more likely a volcanogenic sedimentary protolith is suggested for most of the rocks within this unit.

Onpr — **Rusty schist member.** A medium to dark gray, medium-grained, moderately rusty weathering and locally graphitic, quartz-muscovite± sillimanite schist and granofels. Minor amounts of light gray, fine- to medium-grained, plagioclase-quartz-biotite granofels may be present within the unit.

Onpm — **Mixed rocks member.** A lithologically heterogeneous unit exposed primarily on the northeast-trending peninsula in the northern part of Sheepscot Pond. Rock types include: (1) Medium to dark gray, fine- to coarse-grained, slightly to moderately rusty weathering, quartz-plagioclase-cummingtonite-garnet±hornblende± biotite gneiss. Rock of this lithology is exposed primarily along the southeastern margin of the unit. (2) Light gray to greenish gray, medium- to very coarse-grained, diopside-biotite marble and associated calc-silicate granofels. (3) Medium gray, medium- to coarse-grained, porphyroblastic, slightly rusty weathering, plagioclase-quartz-biotite-garnet±muscovite schist interlayered with very feldspathic granofels. Layering, where present, ranges from 2 to 15 cm in thickness. Garnet porphyroblasts are up to 4 cm across. (4) Light gray, fine- to medium-grained, plagioclase-quartz-biotite gneiss and granofels.

Casco Bay Group

Ordovician and Ordovician (?)

Osp — **Spring Point Formation.** Dark gray, medium to fine-grained, amphibolite. Locally the amphibolite is interlayered with light gray, fine-grained, quartz-plagioclase gneiss and granofels. These rocks have been interpreted to represent metamorphosed volcanic rocks (West and others, 2004). The Spring Point Formation is poorly exposed along the eastern edge of the Razorville quadrangle, but more extensive exposures can be found to the east in the adjacent Washington quadrangle (West, 2004). A U-Pb zircon age of 469 ± 3 Ma from this unit in the Washington quadrangle has been interpreted to represent the age of eruption (Tucker and others, 2001).

Oce — **Cape Elizabeth Formation.** Light gray to medium gray and locally silver gray, medium-grained, quartz-plagioclase-biotite±garnet±sillimanite schist interlayered with light-gray, fine-grained, quartz-plagioclase micaeous granofels. Schistose layers are typically non-rusty weathering and generally lack aluminosilicate minerals, and the granofels is noticeably feldspathic. The contacts between the schist and granofels are generally sharp and layering is typically on the order of 2 to 15 cm thick. Minor calc-silicate granofels and rare amphibolite layers up to 1 meter thick are present. Variably deformed, muscovite, garnet and tourmaline-bearing pegmatite layers, lenses and boudins are locally abundant.

Oceh — **Hibberts Corner member.** Light gray to medium gray, fine-grained, quartz-plagioclase-actinolite±diopside-biotite±grossular garnet granofels and gneiss interlayered with medium gray, fine-grained quartz-plagioclase-biotite granofels. The layers are less than 6 cm thick and the rocks are typically heavily jointed and weather to a slabby appearance. This unit was originally recognized and mapped by Pankiwskyj (1976).

Ocec — **Calc-silicate member.** Light gray to nearly white, fine-grained and thickly layered, quartz-plagioclase granofels and gneiss. These rocks are characteristically found in thick, well-jointed layers up to 75 cm in width. Thin sections reveal a rock dominated by highly recrystallized fine-grained layers of quartz and plagioclase with minor amounts (< 1% each) of hornblende, diopside, biotite, white mica, sphene, zoisite and allanite. In addition, this unit contains minor amounts of medium gray, fine-grained, slabby weathering, quartz-plagioclase-biotite granofels interlayered with light gray, fine-grained, calc-silicate gneiss.

Oc — **Cushing Formation.** Light gray, fine- to medium-grained, plagioclase-quartz-biotite gneiss and granofels. Lesser amounts of light gray, fine-grained calc-silicate granofels and amphibolite may also be present. This unit is very poorly exposed in the Razorville quadrangle.

Ocwc — **Wilson Cove member.** A very distinctive, dark gray to black, fine- to coarse-grained, moderately to intensely rusty weathering, locally magnetite-bearing and/or sulfide rich, quartz-garnet-grunerite-biotite±hornblende gneiss and granofels. Minor amounts of rusty weathering biotite schist and quartzite are also present. Layering may or may not be noticeable as it is often obscured by deep rusty weathering. This unit is interpreted to represent metamorphosed iron-rich deposits.

Oca — **Amphibolite member.** Dark gray to black, fine- to medium-grained, locally garnet-bearing amphibolite. Lesser amounts of light gray, fine- to medium-grained, quartz-plagioclase-biotite gneiss and variably deformed pegmatite may also be present. This unit is interpreted to represent metamorphosed mafic igneous rocks.

Stratigraphic Sequence Uncertain

Ordovician and Ordovician (?)

Ocm — **Crummett Mountain formation** (new name). Medium gray, slightly to moderately rusty weathering, medium-grained to coarse-grained, graphite-bearing, quartz-plagioclase-garnet-staurolite-andalusite mica schist with minor amounts of interlayered feldspathic and micaeous granofels. The schists are characterized by their rusty weathering, the presence of dark gray to black porphyroblasts of staurolite and andalusite (the dark color is due to graphite inclusions), small (generally less than 3 mm) garnets, and discontinuous complexly folded quartz segregations (0.5 to 5 cm thick) that locally contain coarse-grained (up to 8 cm) pink andalusite. Light gray, fine-grained, slabby weathering, biotite granofels and calc-silicate gneiss is present in some places. In addition, along the southeastern margin of the outcrop belt, dark gray to charcoal colored, moderately rusty weathering, fine-grained granofels is locally present. Thin sections from this fine-grained rock reveal a mylonitic texture. The Crummett Mountain formation is interpreted to be fault-bounded within the Razorville quadrangle for the following reasons: (1) to the northwest the unit is bounded by the Sandhill Corner mylonite zone and rocks similar to those of the Crummett Mountain formation have not been found northwest of this mylonite zone, (2) the contact with the Cape Elizabeth Formation along the southeastern margin of the unit appears sharp and the local recognition of mylonites along this margin suggests a tectonic rather than stratigraphic contact, and (3) schists of the Crummett Mountain Formation have mineral assemblages (andalusite+staurolite) that appear to reflect lower grade metamorphic conditions than schists in the surrounding Cape Elizabeth Formation which are commonly migmatitic and locally contain abundant sillimanite.

Ocmc — **Calc-silicate member.** Greenish-gray to light gray, fine-grained, quartz-plagioclase-actinolite± calcite granofels distinctly interlayered with light gray to purplish-gray, fine-grained quartz-plagioclase-biotite granofels. Layers range in thickness from 2 to 8 cm, with calc-silicate granofels being more abundant than biotite granofels in most exposures. Minor amounts of interlayered medium gray, moderately rusty weathering, medium-grained mica schist can be found at some exposures. Nearly all exposures of these rocks are characterized by complex small scale folding in multiple orientations and multiple generations.

Ospg — **Sheepscot Pond Gneiss.** This unit contains a variety of rock types, any number of which may be interlayered at a given exposure. Although the proportion of individual rock types varies from place to place, the following rock types are listed roughly in order of overall decreasing abundance: (1) light gray, medium- to coarse-grained, quartz-K-feldspar-plagioclase-biotite±muscovite gneiss, (2) light to medium gray, medium- to coarse-grained, quartz-plagioclase-biotite-hornblende±clinopyroxene gneiss, (3) light gray, very coarse-grained to pegmatitic, K-feldspar-quartz±biotite± muscovite±garnet±tourmaline gneiss (deformed granitic pegmatite), (4) dark gray, medium-grained, plagioclase-hornblende±biotite gneiss and amphibolite, and (5) light gray, medium-grained, magnetite-bearing, quartz-plagioclase-biotite gneiss. Layering ranges from 0.2 to 50 cm in thickness and contacts between layers are sharp. Most exposures are dominated by quartz-feldspar gneisses (types 1-3 above) with thinner interlayers of hornblende-bearing gneisses or amphibolites. The Sheepscot Pond gneiss is interpreted to represent highly deformed and recrystallized igneous rocks. This unit is on strike with what was mapped by Newberg (1985) as the Sheepscot Pond Granite in the Palermo quadrangle and subsequently shown as the Sheepscot Pond granite gneiss by Tucker and others (2001). A U-Pb zircon age of 474 ± 2 Ma from a "granitic gneiss" (type 1 above) just north of the Razorville quadrangle (in the southern part of the Palermo quadrangle) has been interpreted to represent the original crystallization age of this rock (Tucker and others, 2001).

Rocks of Uncertain Lithotectonic Belt

Devonian-Ordovician (?)

DOb — **Burkettville Complex.** Medium gray, fine-grained to medium-grained, quartz-plagioclase-biotite gneiss and minor light gray to greenish gray calc-silicate gneiss interlayered with light gray, medium-grained to pegmatitic, strongly foliated, locally lineated, biotite granite gneiss and garnet-bearing, muscovite granite gneiss. This unit is somewhat poorly exposed in the southeastern corner of the Razorville quadrangle, but more extensive exposures can be found to the east in the Washington quadrangle (West, 2004).

Fredericton Lithotectonic Belt

Silurian-Ordovician (?)

SOb — **Bucksport Formation.** Well bedded purplish-gray, fine-grained quartz-plagioclase-biotite granofels and greenish-gray, fine-grained plagioclase-quartz-actinolite-diopside granofels. A lens of this unit is inferred to underlie an area of no outcrop in the southeast part of the Razorville quadrangle, based on bedrock exposures in the adjacent Washington quadrangle to the east.

HIGHLY DEFORMED ROCKS

scm — **Sandhill Corner mylonite.** Nearly all rocks within this zone are mylonitic containing steeply dipping mylonitic foliations and locally subhorizontal mineral lineations. Several different rock types, often interlayered at a given exposure, can be found within the zone, including: (1) Dark gray to medium gray, fine-grained mylonite characterized by porphyroblasts of feldspar (up to 1 cm) and muscovite (often smeared out and lineated on mylonitic foliation surfaces) set in a dark colored, fine-grained to aphanitic matrix. (2) Light gray, fine-grained to medium-grained, locally garnet- and/or tourmaline-bearing, biotite-muscovite granitic mylonitic gneiss. (3) Light gray to medium gray, extensively shear banded and/or protomylonitic, mica schist and micaeous granofels. Protoliths for the Sandhill Corner mylonite likely include rocks of the Cape Elizabeth Formation together with granitic rocks common in the Cape Elizabeth where less deformed. Significant strain gradients exist along and across the Sandhill Corner mylonite zone, and the mapped boundaries with ordinary Cape Elizabeth Formation are typically gradational. In places, protomylonitic and other highly deformed rocks can be found along the margins of the mylonitic zone. The Sandhill Corner mylonite was originally recognized and mapped by Pankiwskyj (1976) and is part of the regionally extensive Norumbega fault system. A variety of kinematic indicators (e.g., mica fish, rotated porphyroblasts, shear bands, etc.) suggest the zone developed in response to right-lateral strike-slip movement (West and Hubbard, 1997). $^{40}Ar/^{39}Ar$ muscovite ages from this mylonite zone have been interpreted to reflect a late Carboniferous to early Permian age for the mylonitic deformation (West and Lux, 1993).

jcc — **Jones Corner cataclasite.** Rocks within this fault zone show evidence for both early ductile mylonitic deformation and later brittle deformation including the extensive development of pseudotachylyte and cataclasite. Rocks within the zone are dominated by medium gray, fine-grained to medium-grained, feldspathic mica schist and mylonitic quartz-feldspar-biotite gneiss. Numerous small-scale brittle faults rotate and contort compositional layering and foliation. Nearly all exposures within the zone contain dark gray to black, aphanitic veins of pseudotachylyte and/or cataclasite. These veins, up to 3 cm in width, are discontinuous and typically discordant to the foliation. Inclusions of the surrounding country rock can often be found within some of the larger veins and cross-cutting relationships suggest multiple episodes of pseudotachylyte/cataclasite generation. Attempts to trace the fault zone to the north were unsuccessful. No attempts were made to trace the zone to the south into the Jefferson quadrangle.

INTRUSIVE ROCKS

Devonian-Silurian(?)

DSbg — **Foliated biotite granite.** Light to medium gray, medium-grained to coarse-grained, moderately to strongly foliated, locally lineated, biotite granite, locally containing muscovite and/or garnet. Minor amounts of medium gray, medium-grained, moderately foliated, biotite granodiorite. Many outcrops contain variable amounts of boudinaged muscovite-bearing granitic pegmatite. These rocks are most likely related to the Haskell Hill granite gneiss exposed along strike to the south in the adjacent Jefferson 7.5' quadrangle. A U-Pb zircon age of 408 ± 5 Ma from the Haskell Hill granite gneiss in the Jefferson 7.5' quadrangle has been interpreted to represent the original crystallization age of the intrusion (Tucker and others, 2001).

DSbgx — **Foliated biotite granite with xenoliths.** Light to medium gray, medium-grained to coarse-grained, moderately to strongly foliated, biotite± muscovite granite with abundant metasedimentary xenoliths up to several meters across. Xenoliths are most commonly biotite granofels and calc-silicate gneiss lithologically similar to the Bucksport Formation of the adjacent Washington quadrangle (West, 2004).

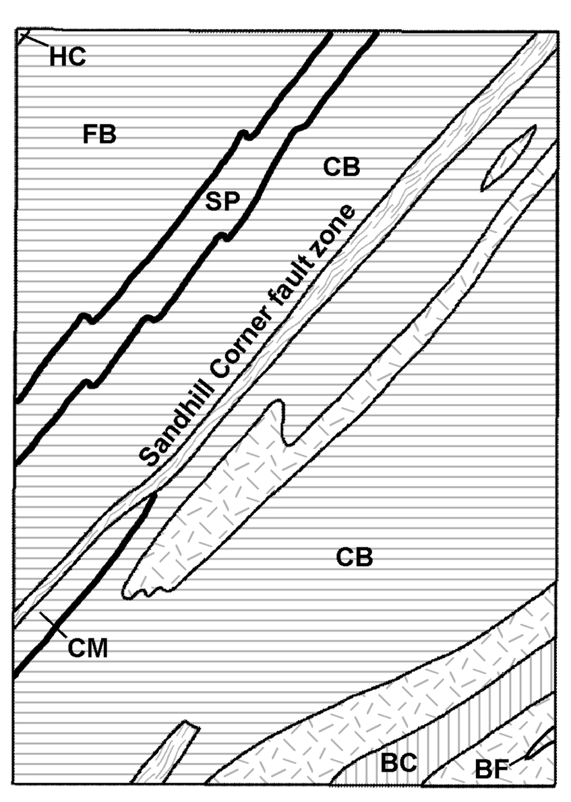
Devonian-Silurian

DSfls — **Foliated porphyritic shonkinite of the Lincoln Sill** (of Trefethen, 1937). Dark gray to purplish-gray, moderately to strongly foliated, porphyritic, actinolite-biotite shonkinite (alkali feldspar syenite). Orientation of matrix minerals (actinolite and biotite) defines the foliation, and purplish-gray to white alkali feldspar megacrysts are strongly aligned within the plane of foliation. Most exposures of the foliated shonkinite in this quadrangle contain variable amounts of foliated biotite granite. In this quadrangle, the mapped contacts of the shonkinite are tentatively interpreted to be tectonic rather than intrusive, based on the severe deformation of the rocks. Extensive exposures of undeformed varieties of the shonkinite are well exposed to the east in the adjacent Washington 7.5' quadrangle (West, 2002). A U-Pb zircon age of 418 ± 1 Ma from the Lincoln Shonkinite in the Washington quadrangle has been interpreted to represent the original crystallization age of the intrusion (Tucker and others, 2001).

Silurian

Sgn — **Lake St. George granite gneiss.** Light to medium gray, medium-grained, strongly foliated and locally lineated, biotite-quartz-plagioclase-alkali feldspar gneiss. Locally, medium to dark gray, moderately to strongly foliated hornblende-biotite granodiorite gneiss is associated with the granite gneiss. Weakly to moderately deformed granitic pegmatite can also be found within this unit. A U-Pb zircon age of 422 ± 2 Ma from the Liberty 7.5' quadrangle is interpreted to represent the original crystallization age of the intrusion (Tucker and others, 2001).

MAJOR GEOLOGIC FEATURES



Highly deformed rocks

Foliated intrusive rocks

Central Maine Lithotectonic Belt
HC - Hutchins Corner Formation

Liberty-Orrington Lithotectonic Belt
FB - Falmouth - Brunswick Sequence
SP - Sheepscot Pond Gneiss
CB - Casco Bay Group
CM - Crummett Mountain formation

Uncertain Lithotectonic Belt
BC - Burkettville Complex

Fredericton Lithotectonic Belt
BF - Bucksport Formation

Fault

EXPLANATION OF SYMBOLS

- Bedrock outcrop with no structural information given.
- Strike and dip of foliation or schistosity (inclined, vertical).
- Strike and dip of fold axial plane.
- Trend and plunge of fold axis.
- Trend and plunge of lineation.
- Strike and dip of joint (inclined, vertical).
- (4) Location sampled for $^{40}Ar/^{39}Ar$ isotopic analysis (see Table 1 for results).

EXPLANATION OF LINES

Contact between mapped units (well located, approximately located, poorly located).

Fault, inferred from stratigraphic relationships and map pattern (well located, approximately located, poorly located).

Structural boundary between highly deformed rocks and less highly deformed rocks. Nature of this boundary is uncertain; it may be gradational.

Table 1. Experimental age determinations by $^{40}Ar/^{39}Ar$ analysis.

Locality	Mineral	Age (Ma)	Significance
1	hornblende	363 ± 3	last cooling below ~ 500°C
1	biotite	355 ± 3	last cooling below ~ 300°C
2	muscovite	358 ± 3	last cooling below ~ 350°C
3	muscovite	340 ± 3	last cooling below ~ 350°C
4	muscovite	352 ± 3	last cooling below ~ 350°C
5	muscovite	ca. 345	last cooling below ~ 350°C
5	muscovite	ca. 290	timing of mylonitic deformation

Notes: Results for hornblende and muscovite are from step-heating, incremental argon release experiments. Biotite age is a total gas age from a fusion experiment. Age reported in millions of years ago (Ma) with uncertainty of ± 2 sigma, including J-value uncertainty.

Source: D. P. West, Jr., analyst at University of Maine geochronology lab. Results for localities 1-4 are from West (1993). Results for locality 5 are from sample Raz-43, presented by West and Lux (1993).

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-65
Mesozoic Era	Cretaceous Period	65-145
	Jurassic Period	145-200
	Triassic Period	200-253
Paleozoic Era	Permian Period	253-300
	Carboniferous Period	300-360
	Devonian Period	360-418
	Silurian Period	418-443
	Ordovician Period	443-489
	Cambrian Period	489-544
Precambrian time		Older than 544

* In millions of years before present. (Okulitch, A. V., 2002, Échelle des temps géologiques, 2002: Commission géologique du Canada, Dossier Public 3040 (Série nationale des sciences de la Terre, Atlas geologique) - RÉVISION.)

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